

SOIL EROSION IN CZECHOSLOVAKIA

Eroze půdy v ČSSR. — Výzkum eroze půdy v ČSSR se v širším měřítku rozvíjí teprve v posledních 15—20 letech. Jeho nositeli jsou pracoviště hydrologická, agromeliorační, pedologická a geografická. Vzhledem ke značné členitosti reliéfu a velké pestrosti půd, stává se eroze půdy v ČSSR stále více předmětem studia hlavně pedologů a geomorfologů, kteří také přikročili k jejímu systematickému staničnímu pozorování. Na základě současných poznatků je možno stanovit, že na území našeho státu nejvíce působí na rozvoj splachu a stružkové eroze půdy členitost území, přívalové deště, výskyt hlinitých i hlinitopísčitých půd a porušení souvislého vegetačního krytu. Tytéž faktory spolupůsobí i při vzniku a vývoji strží. Hustota stržové sítě, především její zřetelný růst směrem z Českého masivu do Karpat, jsou však ovlivněny spolupůsobením dalších faktorů, k nimž patří intenzita neotektonických pohybů, různé druhy geologického podkladu, historický vývoj osídlení a polních cest. Eroze půdy působená větrem se projevuje v ČSSR především v nížinách na plochách s vhodnými klimatickými a pedologickými poměry, nedostatečně chráněných vegetací a na malých územích ve vysokohorských polohách.

The history of research

The research of the urgent agricultural problems of the soil erosion and the protection against it began to develop more expressively in Czechoslovakia in the last 15—20 years on the pedological, hydrological, agromeliorative and geographic working places. The pedologers and geomorphologers especially began to notice besides the proper research in the dissected and geomorphologically variegated relief of our territory the phenomena of the accelerated erosion.

When studying the origin of the earth pillars in the Plzeň area, C. Purkyně (1909), who supposed correctly the narrow and deep gullies with vertical walls to be formed by occasional water from torrential rains, noticed the erosion microforms. J. Spirhanzl (1946, 1952) studied the sheet wash and the gully erosion from the pedological point of view and he was the first, who summed up the knowledge about the water and eolian soil erosion in a complete monographic study in our country. B. Mařan and O. Lhota (1947, 1953) studied the water erosion with regard to the solving of the questions of the protection of agricultural and forest soil against the erosion. The soil denudation was studied on the small experimental fields in the Ještědské hory Mts., on the soil skeletons, and in South Moravia.

The experimental methods were introduced successively into the soil erosion research by the research workers of the chairs of hydromelioration in Praha and Brno and by the research workers of the institutes for the research of the water economics. J. Dvořák (1955) realized the experiments on small areas with the help of artificial rain, with the soil erosion and denudation; M. Holý (1955, 1956) studied the influence of the slope shapes on the sheet erosion and realized numerous laboratorial analyses of the eroded soil in the district Roudnice nad Labem. He compiled further a map of the sheet erosion for a part of the SW Bohemia.

A great initiative for the organisation of the soil protection against erosion was shown by J. Cablík and K. Jůva, who improved the modes of the soil protection against the accelerated erosion (the high-school textbook of 1954 and 1963). V. Kozlík used in surroundings of the village Budmeřice the method of the test fields, connected with the artificial and natural watering. The acquired results were then used in the proposal of the furrowing — one of the systems of protection against the soil erosion. He followed here the point of view of the effectiveness and economy of this kind of the antierosion soil protection. D. Zachar (1958, 1960) was looking to the practical needs of the forest economics when investigating the soil erosion in more parts of Slovakia. He gave a summary of the results of the research, where he used especially the pedologic and the metric methods, in a monography.

The hydrologic methods of the erodologic research supplement well the investigations of the soil erosion in the given river basin. According to O. Dub (1955, 1956) it is possible to judge the intensity of the soil erosion on the basis of the quantity of the fluvial deposits in a certain part of the water course. The measuring of these deposits was carried out on some Slovakian rivers by D. Almer (1955), B. Nather and J. Szolgay (1958), whose results are completing the experimental material for the study of the soil erosion suitably. The measuring of the quantity of the fluvial deposits on Czech rivers was carried out by the workers of the State Hydrologic Institute in Praha.

The soil erosion being one of the geomorphologic phenomena of the slope modellation, the geomorphologic methods prove very useful at its study. These methods are used especially by the physical geographers, who investigate the accelerated erosion and who carry out even the experimental research of the sheet wash of soil on the research objects in last time. The morphometric indexes were used when the map of the density of the sheet wash pattern was elaborated in Slovakia by Š. Bučko and V. Mazúrová (1955, 1956, 1958), in Czech countries by O. Stehlík and K. Gam (1956, 1957). O. Stehlík studied even the gully erosion in South Moravia. The historical data about the soil erosion in the region of Brno were worked up by Z. Láznička (1957, 1959), who paid attention even to the recent soil erosion. J. Demek (1960), T. Czudek (1962) and J. Demek — H. Seichterová (1962) studied the sheet wash on more

places of Moravia. Z. Lochman (1960) contributed to the recognition of the genesis of the erosion microforms. The gully erosion and the sheet one were studied by P. Plesník (1958) in the areas of the upper forest border in Slovakia; in contradistinction to it J. Košťálik investigated the intensity of the erosion processes on the loess soil and V. Lobotka (1955, 1963) on the flysch slopes with terraces.

In the interest of the further basic research of the soil erosion in ČSSR it is necessary to coordinate all the part investigations and to arrange them with regard to the needs of the praxis and of the theoretical development of the science of the soil protection against erosion.

The method of the map compilation

The map of the soil erosion on the territory of ČSSR gives the data of the density of the gully pattern, of the intensity of the sheet wash and of the rill soil erosion and of the intensity of the eolian erosion. The data of the density of the gully pattern were elaborated by the Geographical Institute of the Czechoslovak Academy of Sciences for the territory of the Czech countries and by the Geographical Institute of the Slovakian Academy of Sciences for the territory of Slovakia. The detailed topographic maps were used as the basic information source for the study of the density of the gully pattern. On these maps the gullies are drawn in their real shape and dimension by striking common symbols. The density of the gully pattern was established on these maps for the whole territory of ČSSR by measuring of the length of the gully cuts in squares of the territory of an area of 4 km². According to the frequency of the occurrence of the values of the gully pattern on these areas, three characteristic degrees of density were settled: 1) areas with an insignificant density of the gully pattern (0,0—0,1 km/km²), 2) areas with the mean density of the gully pattern (0,1—1,0 km/km²) and 3) areas with a considerable density of the gully pattern (1,0 and more km/km²). On the basis of this scale, with regard to the total characteristic of the shape of the surface and to some typical features of its actual development, isolines of the same density of the gully pattern were drawn up for the whole territory of ČSSR by the generalization of the borders of the specific squares. The above mentioned geomorphologic studies were completed on the one hand by the confrontation of the results of the measured gully pattern on detailed topographic maps acquired for the same territory by different authors, on the other hand by the general terrain investigation of smaller areas with the typical occurrence of gullies, where the attention was paid not only to the study of the density of the gully pattern but even to the natural and cultural conditions of their development.

The data of the dislocation of the sheet wash and the rill erosion of soil were prepared by the chair of Hydromelioration of the Construction Faculty of the Czech Technical High School in Praha. The materials of the State Plan of Water Economics were used as basic information, in which the intensity of the water erosion was judged within the scope of the individual river basins on the basis of their angle of slope and of the information of the agricultural plants. The data of the State Plan of Water Economics were verified by the detailed research in the river basins of Berounka and Ploučnice. The geological, geomorphologic, pedologic, hydrologic, climatic and biological factors were evaluated here and numerous observations were carried out directly in the terrain. The investigations showed that the lists of the areas threatened by the soil erosion elaborated by the State Plan of Water Economics correspond to the reality and that they may be used safely as basic material. At the map compilation the percentage of the affecting of the agricultural soil by the water erosion in the squares of the area of 81 km² was established for the whole territory of ČSSR. The degree of threatening was determined on the basis of the ratio of the total area of the specific square to the area of the agricultural soil subjected to water erosion inside this square. The specific squares, in which less than 25 % of agricultural land are suffering water erosion, 2) the specific squares, in which 25—50 % of agricultural land are suffering water erosion, 3) specific squares in which 50—75 % of agricultural land are suffering erosion and 4) specific squares, in which more than 75 % of agricultural land are suffering water erosion, were distinguished here. By the interpolation of the borders of these squares isolines of the threatening of agricultural land by water erosion were acquired and the forested areas which are not suffering erosion were excluded of the areas limited by these isolines.

The data of the dislocation of the eolian soil erosion on the territory of ČSSR were elaborated by the chair of hydromelioration of the Construction Faculty of the Czech Technical High School in Praha on the basis of the materials of the State Plan of Water Economics acquired of the reports of the agricultural plants, of the erodological bibliography and on the basis of information of the Geographical Institute of the Slovakian Academy of Sciences, based on the evaluation of the shapes of the relief and on the basic climatic data.

Main reasons of the development of erosion phenomena in ČSSR

The legality of the occurrence of the water erosion is given by the mutual grouping of the erosion factors and by the influencing of their more or less expressive activity by the local conditions. The most important factors, which have to be investigated first of all in our climatic conditions, are the climatic

and hydrologic, the geomorphological (especially the angle and the length of slopes), the soil and geological, the vegetation and the economic-technical ones.

The water erosion reflecting on the destructional, transportational and sedimentary activity of the rainy water falling on the soil surface and running away at its inclination in form of the surface discharge, depends first of all on the atmospheric precipitations. The investigation of the erosion phenomena led to the recognition, that especially the torrential rainfalls which are expressively destructing the surface by the energy of the incidence of drops and give at the high intensity and short duration considerable values of surface discharge, are dangerous in the natural conditions of ČSSR. At approximately the same distribution of the torrential rainfalls on the territory of ČSSR further factors especially the angle and the length of slope, given by the division of the territory, influence the extent of the discharges.

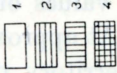
ČSSR is characterized by a considerable division of its surface. Its great part, especially on the territory of Slovakia, has a hilly, submountainous to mountainous character. As consequence of this division, the great percentage of soils on slopes can be considered, on which the erosion activity of the surface water causing the origin of different kinds of the sheet and gully erosion exerts its influence. In accordance with the theoretical study of the influence of the angle and of the length of slope on the origin and on the course of the water erosion and according to the results of the research in the terrain, it may be said, that the water erosion in ČSSR reflects expressively especially in the strong dissected areas.

Further investigations showed that the occurrence of erosion processes and especially their intensity, are influenced by the soil conditions. The loamy and even loamy sandy soils are most bent to the water erosion. This recognition (but it is necessary to take into consideration the influence of the angle and of the length of slope) is proved by the occurrence of the water erosion on the Pleistocene loess loam in Central, East and West Bohemia, on the loamy deposits along the rivers Morava, Dyje, upper Odra and their tributaries in Moravia, in the flysh zone of Slovakia on the loamy sandy soils formed on debris of the Czech frontier mountains and of the Českomoravská vysočina Highland and on the sandy loamy soils of the Slovakian mountains.

The occurrence of the water erosion on these soils is influenced by their vegetation cover. Vegetated soils resist to erosion comparatively well, as the vegetation protects the soil of the direct incidence of the rain drops and of the destructive and transportational activity of the surface water. The best protection is the forest cover with a dense undergrowth, the permanent meadows and the pastures with developed turf. An insufficient protection is formed by agricultural produce. The agricultural soils and the soils of the highest mountain ranges above the border of the forestation are mostly sub-

MAP OF SOIL EROSION IN ČSSR

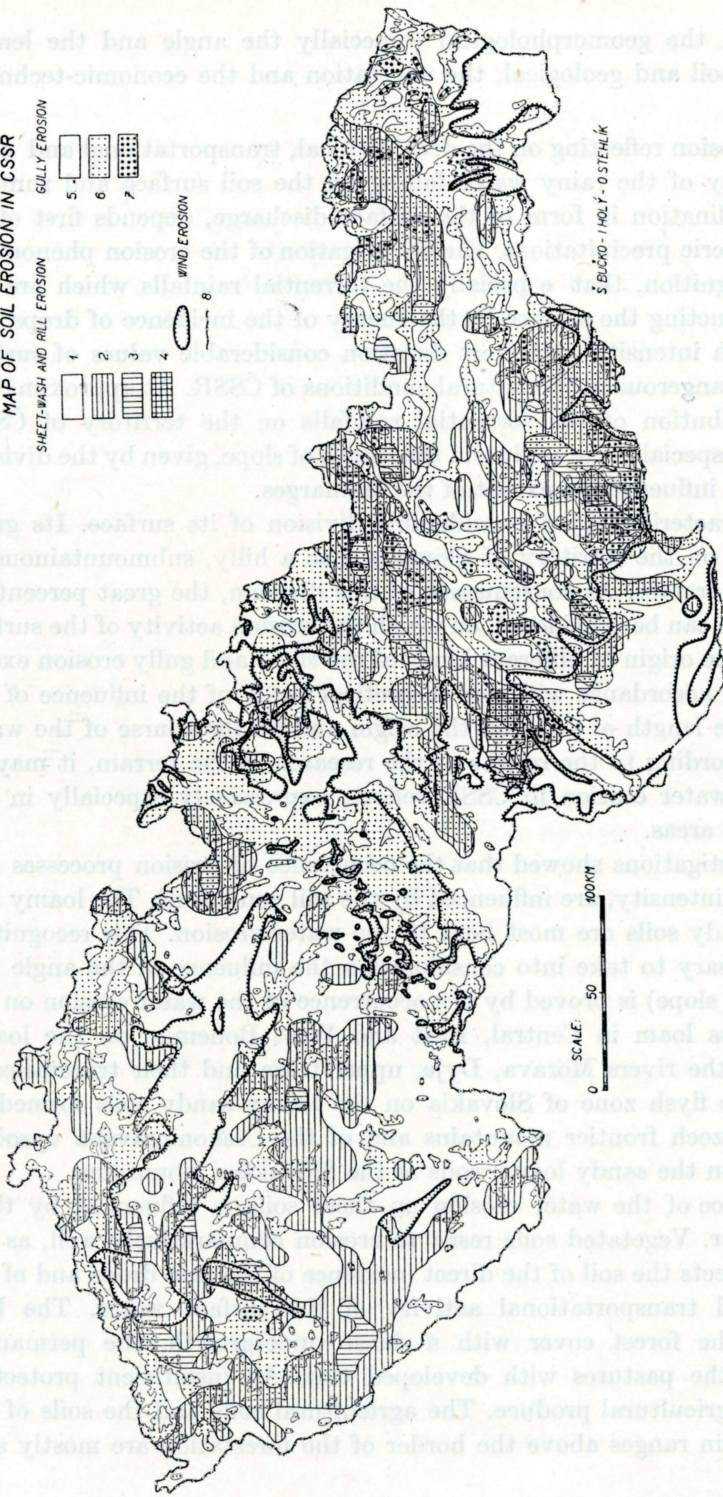
SHEET-WASH AND RILL EROSION



GULLY EROSION



WIND EROSION



MAP OF SOIL EROSION

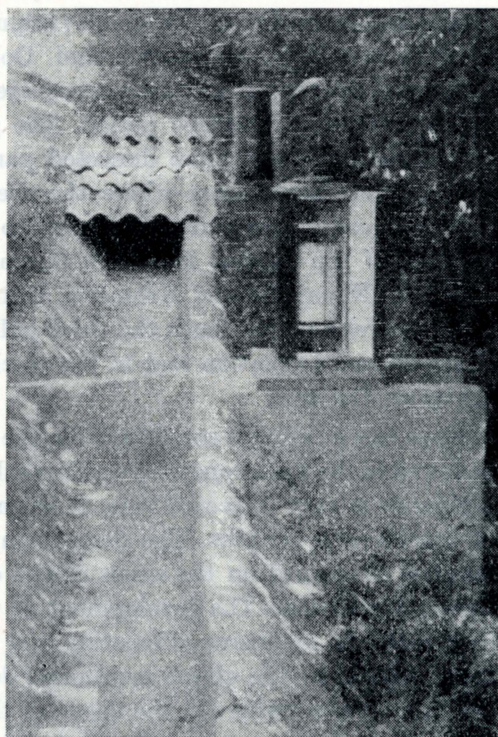
1. less than 25% of the area of the territory
2. 25%—50% of the area of the territory
3. 50%—75% of the area of the territory
4. more than 75% of the area of the territory
5. areas of insignificant density of the gully pattern (0—0,1 km²/km²)
6. areas of moderate up to average density of the gully pattern (0,1—1,0 km²/km²)
7. areas of intense density of the gully pattern (more than 1 km²/km²)
8. the border of the state

jected to the water erosion. This fact reflected fully on the establishment of the occurrence and of the extent of the water erosion in ČSSR.

The economic-technical conditions are of main importance for the origin of the water erosion. The water erosion occurs more expressively in areas, where the right principles of the land utilization are not adhered to, i.e. where the contour cultivation on the slope lands is not carried out, where the boundaries of water economic significance are abolished (their task is to interrupt the surface discharge down-slope) and too large acres of land are formed, where the field ways are not designed and carried out correctly, where the exceeding cultivation of woods is carried out. As these circumstances are not uniform on the territory of ČSSR and as their arrangement is planned (in some areas the necessary measures are taken), they were not included fully at the establishment of the legality of the occurrence of the water erosion.

We cannot but conclude that it may be said on the basis of the theoretical analysis of the problem and of the proving of the acquired results in the terrain and on the basis of extensive map studies, the occurrence of the water erosion in ČSSR and its dislocation to be influenced predominantly by the division of the territory and by the soil and vegetation conditions. These factors reflected very expressively in different combinations at the establishment of the legality of the occurrence of the water erosion in ČSSR and their investigation made possible to acquire a reliable basis for the compilation of the map of the water erosion.

The visible growth of the density of the gully pattern in the direction from west to east may be noticed in Czech countries. In the west part of the Czech Massif the greatest gully density is concentrated in the areas consisting of rocks of the Permian and Cretaceous period, where the kaolinic and arcosis sandstones are subjected to the destruction by the running water. The greatest gully concentrations are found near the village Plasy, north of the town Plzeň and in



1. Collecting concrete trough at the erosion research fields at Velké Žernoseky.

Photo M. Holý

the space among the towns Rakovník, Louny and Žatec, further between the towns Litoměřice and Liberec and north of the town Náchod. On a considerable area but in a smaller concentration, the gullies appear in the foothills of the Krkonoše Mts., Orlické hory Mts. and on the Českomoravská vrchovina Highland. The origin of these gullies is conditioned especially by the Holocene deepening of the water courses, which even the vertical erosion of the occasional water flows in the valley heads filled up with Pleistocene sediments, is connected with. The reasons of the development of the gullies in the highlands and mountainous countries of the east margin of the Czech Massif in Moravia and Silesia are similar; the greater activity of the erosion processes is caused here by the greater intensity of the young tectonic movements.

In the zone of the Subcarpathian depressions the loess covers and the loose or a little consolidated sediments of Quaternary and of the late Tertiary offer very suitable conditions for the development of the gullies. The gully development in the Dyjskosvratecký and Dolnomoravský úval was considerably supported by people, as these areas are exploited agriculturally very intensively since the Neolithic period. The greatest concentration of the gullies can be found in the more dissected parts of the graben between the towns Znojmo and Brno, from where the area proceeds along the margin of the Českomoravská vrchovina Highland to the town Boskovice and along the SE foot of the Central Moravian Carpathians among the towns Kyjov, Uh. Hradiště, Napajedla and Kroměříž. In the space of the Moravian gate and of the Ostravská pánev Basin the thick gully pattern was formed on the deposits of the glacial formation and in the thick loess loam covers especially east of the town Ostrava.

Even more suitable conditions for the development of the gully erosion can be found in the flysh zone of West Carpathians. The surface of the hillylands and highlands is very dissected here, it has a considerable relief energy and slopes of considerable lengths. The deep loamy sandy regolith and the solifluction mantles developed on the zones of the claystones which occupy large areas during Pleistocene. The development of the agriculture was closely connected here with the extensive afforesting and with the clearance of the land in the relief formed by the above mentioned deep regolith. It is therefore possible to find almost everywhere in the space of the outer Carpathians large areas with a relatively dense pattern of gully incisions and also the greatest gully agglomerations reaching in extreme cases the values of more than 4 km/km². The greatest gully concentrations can be found in the Těšínská pahorkatina Hillyland, among the towns Frýdek, Č. Těšín and Ostrava, further in the valley head of the river Ostravice and in the valley head of the river Rožnovská Bečva.

The different intensity of the erosion processes is caused in Slovakia especially by the geomorphologic character of the relief, by the petrographical properties of the rocks and the soils developed on them, by the meteorologic

and anthropogenous factors. To the contrary of the Czech countries the relief of Slovakia is with regard to the west Carpathian mountain system very strongly dissected and it has slopes of a great angle. Even the processes of the accelerated erosion show due to it marks of a considerable freshness and intensity.

The prevailing part of the Slovakian territory is occupied by the mountain relief, in which the proper higher massifs, the lower foothills, highlands and hilly lands differ one from another morphologically. The massifs formed by the hard flysh crystalline and volcanic rocks, with the relatively well preserved coherent forests, are characterized by the insignificant gully erosion (the gully density being smaller than $0,1 \text{ km/km}^2$). The considerably afforested foothills, highlands and hilly lands consisting of the relatively less resistant rocks (claystones, shales, crushed dolomites, tuffs and agglomerates) have much more favourable conditions for the gully erosion. The dense gully pattern ($0,5\text{--}2,0 \text{ km/km}^2$) developed in the hilly lands (Myjavská pahorkatina) especially and on the highlands of the flysh (Kysucká vrchovina, Podbeskydská vrchovina, Šarišská vrchovina, Ondavská vrchovina with the exception of the central part) and of the volcanic zone (Krupinská vrchovina, Filakovská vrchovina Highlands). Smaller enclaves with the expressive and fresh gully and rill erosion can be found in the foothills of the mountain massifs of the crystalline (chtelnicko-šípkovské podhůří Malých Karpat, lúčanské a kalnické podhůří Podvážského Inovce, podhůří Gmerského rudohoří) and of the volcanic zone (the foothills Vihorlat and Popričný, the foot layers of the Slánské Mts). The gently modelled forms of these orographic wholes supported the colonization of this territory by peasants and by herdsmen even in the middle ages, but especially in the 15th and 16th century during the so called Valachian colonization. The slope fields, the elementary free grazing, the field ways running down slope and other motives caused the intensive gully erosion on the middle up to strongly inclined slopes ($5\text{--}20^\circ$) and on the a little resistant substratum.

Numerous anthropogenous motives for the accelerated erosion occur due to the dense colonization even in the basin-shaped relief, but with regard to the different natural factors (less rainfalls, smaller expressiveness of the relief) the gully erosion is in the majority of the basins less intensive than in the hilly lands and highlands of the mountain relief. The dense gully pattern ($1,0\text{--}4,0 \text{ km/km}^2$) developed on the loose Neogene and Quaternary rocks (volcanic agglomerates, sandy gravels of Neogene formations, loess loams and rough Deluvial mantles) and on the relatively long slopes of the higher hilly lands of the Horní Nitra, Ipola and Košice basins.

The intensive processes of the gully erosion pass in the higher hilly lands of the Neogene plateaus of the lowland relief in which the various economic activity of people can be observed especially since the middle ages. The little resistant loose rocks of the substratum, the loess loamy soils and the long slopes in-

fluenced the development of the dense gully pattern in the NW, N and NE part of the Podunajská nížina Lowland and of the S part of the Východoslovenská nížina Lowland. The greatest density (more than 2,0 km/km²) of the gully pattern developed on the border of the higher hilly lands with the submountainous steps.

Bibliography

- ALMER D.: Pozorovania plavenín na niektorých slovenských tokoch. Vodohospodár. čas. 1—2, 1955.
- BUČKO Š.: Výmolová erózia v povodí Hornádu. Geogr. čas. 1, 1956.
- BUČKO Š.—MAZÚROVÁ V.: Výmolová erózia na Slovensku, Bratislava, 1958.
- BUČKO Š.: Erózia pôdy v dolnom povodí Váhu. Sborník ČsSZ 1, 1963.
- CABLÍK J.—JŮVA K.: Protierozní ochrana půdy, 2. vyd. Praha, 1963.
- CZUDEK T.: Současná stružková eroze na svazích v okolí Bílovice. Přírodovědní časopis slezský 3, 1962.
- DEMEK J.—SEICHTEROVÁ H.: Eroze půdy a vývoj svahů v současných podmínkách ve střední části ČSSR. Sborník ČsSZ 1, 1962.
- DUB O.: Intenzita erózie a jej stanovenie hydrologickými metódami. Vodohosp. čas. 1—2, 1955.
- DVOŘÁK J.: Metodika výzkumu na zemědělských pozemcích (archiv VÚT) Praha, 1954.
- DVOŘÁK J.: Metody určování povrchového odtoku ze srážek. Vodní hospodářství 8, 1961.
- GAM K.: Přehledná mapa rozšíření strží v Čechách. Vodní hospodářství 1, 1957.
- HOLÝ M.: Šetření o vodní erozi v severních Čechách (archiv Kateder meliorací ČVUT) Praha, 1954.
- HOLÝ M.: Vliv tvarů svahu na průběh vodní eroze. Vodní hospodářství 1—2, 1955.
- HOLÝ M.: Vývoj a směr v mapování půdní eroze, Praha, 1957.
- JANÁČ A.: Metoda určovania stupňa zmytosti pôd. Geogr. čas. 3, 1958.
- KOZLÍK V.: Brázdivý systém v boji proti erózii pôdy. Vodohosp. čas. 1, 1956.
- KOZLÍK V.—MALÍŠ O.—ALENA F.: Ochrana pôdy pred vodnou eróziou, Bratislava, 1961.
- LÁZNIČKA Z.: Stržová eroze v údolí Jihlavy nad Ivančicemi. Práce Brněn. zákl. ČSAV, Brno, 1957.
- LHOTA O.—MAŘAN B.: Výsledky našich pokusů s erozí. Věstník ČSAZV, 1953.
- LOBOTKA V.: Terasové polia na Slovensku. Poľnohospodárstvo 6, 1955.
- LOCHMANN Z.: Příspěvek k poznání geneze erozních tvarů, Sborník ČsSZ 1, 1960.
- MAŘAN B.—LHOTA O.: Výzkum eroze a protierozních opatření na zemědělských a lesních půdách (archiv VÚM), Praha, 1947.
- MAZÚROVÁ V.: Výmolová erózia v povodí Ipla, Geograf. čas. 1—2, 1955.
- NÁTHER B.—SZOLGAY J.: Súčasný stav metodiky výskumu plavenín na tokoch a výsledky tohoto výskumu na Slovensku ako podklad pre posúdenie intenzity erózie hydrologickými metódami. Vodná erózia na Slovensku, Bratislava, 1958.
- PLESNÍK P.: Erózia pôdy v oblasti hornej hranice lesa v Krivánskej Malej Fatre. Vodná erózia na Slovensku, Bratislava, 1958.
- PURKYNĚ C.: Zemní pyramidy a příbuzné zjevy na Plzeňsku. Sborník České společnosti zeměvědné, č. 4, 1909.
- SPIRHZANZL J.: Půda a její zlepšování, Praha 1946.
- SPIRHZANZL J.: Eroze půdy a ochrana proti ní. Praha, 1952.
- STEHLÍK O.: Stržová eroze na jižní Moravě, Praha PBZ, 1954.
- ZACHAR D.: Erózia pôdy, Bratislava, 1960.